Fermilab Directorate

MEMORANDUM OF UNDERSTANDING

FOR THE 2006 MESON TEST BEAM PROGRAM

TXXX

ILC Muon Detector Tests

December 20, 2005

INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory and experimenters from Indiana University, University of Notre Dame, Wayne State University, University of California at Davis, and Fermilab/ILC, who have committed to participate in beam tests to be carried out during the 2006 MTBF program. The memorandum is intended solely for the purpose of providing a budget estimate and a work allocation for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to negotiate amendments to this memorandum which will reflect such required adjustments.

The tests are to study the performance of a set of four prototype muon detector modules. The modules are each 1.25 m x 2.5 m and consist of 64 strips of scintillator oriented at +/- 45º to the edges of the module. Thus far the group has tested two of the modules in Lab 6 using radioactive sources and cosmic rays. The source does not accurately reproduce the energy deposition of a muon in the scintillator, and the cosmic ray rates are too low to map the response of the detectors at sufficient numbers of points on all the strips. Thus we need to test in a beam to determine the strip-to-strip variation in efficiency and the average number of photoelectrons from the modules. The test data will also provide important information about the position-dependence of the response along the strips. Two of the modules have readout at one side of the counter and the other two have double-sided readout. The tests will provide a quantitative answer to whether it is necessary to use double-sided readout or not.

We have reported earlier test results of a smaller pre-prototype module at the March, 2005 ILCWG meeting at Stanford, and source and cosmic ray tests of the first two prototype modules at the August, 2005 ALCPG meeting at Snowmass.

This proposal requests test beam time during 2006. We wish to initiate testing prior to the March, 2006 accelerator shutdown, and continue the tests after the shutdown.

I. PERSONNEL AND INSTITUTIONS:

Spokesman and physicist in charge of beam tests:	Robert Abrams, Indiana University
Fermilab liaison:	Erik Ramberg

The group members at present and others interested in the test beam are:

1.1 Fermilab: Gene Fisk and Caroline Milstene

Other Commitments:
D0 and ILC Muon Studies Co-Chair: Gene Fisk

ILC Simulations: Caroline Milstene

1.2 University of Notre Dame: Mitchell Wayne

Other Commitments: D0 Experiment

1.3 Wayne State University: Paul Karchin

Other Commitments:
CDF Experiment: Paul Karchin

1.4 University of California at Davis: Mani Tripathi

Other Commitments: US-CMS

1.4 Indiana University: Rick Van Kooten, R. Abrams

Other Commitments:
D0 Experiment: Rick Van Kooten, R. Abrams

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The tests are to be performed in the MTEST beam line, in the MT6 enclosure. We are considering 2 locations in the MTEST enclosure. One is in the MT6-B1 area,. The second is in the MT6-B4 area, or downstream of the movable table in MT6-B3. In both of these locations the shielding wall and the electrical conduits along the wall limit the movement of the apparatus toward the west, such that approximately 20% of the detector could not be moved into the beam. To pass the beam through the remaining parts of the detector requires removing the detector from its cart and turning it 180º about a vertical axis, and replacing it on the cart. See Appendix II for a diagram. We note that there is more space available in the MT6-B4 area.

2.1.2 We are requesting control to steer the beam so that we are able to move the beam to hit several strips for a given position of the set of counters. This would enable us to reduce the number of accesses required to reposition the apparatus. A typical run entails a horizontal scan to take measurements on all 64 strips at a particular vertical position. Then the set of counters is moved up or down to another vertical position for the next horizontal scan. We intend to make about 8 scans. At each position the fraction of beam counts in coincidence with the counters is recorded on scalers. In addition we will collect pulse information on ADCs to analyze the charge collected.

2.1.3 Several modifications to the MTEST area are needed to support the tests. Rails for the cart to move the apparatus need to be attached to the floor. We may need an additional cable tray or patch panel to carry the signal cables from the detector to the fast electronics control area. We will need some support to align the apparatus relative to the beam line. In the MT6-B1 location it would be necessary to move the PWCs that is just upstream of the MT6-B2 enclosure to allow room for the apparatus.

2.1.4 Electronics needs.
The number of channels in the system is the following: each of the single-ended readout modules has 64 channels and each of the double-ended readout modules has 128 channels, for a total of 384 channels. For a fully instrumented system, each channel would have a discriminator, and an ADC. This would also require hundreds of cables between the detector and the electronics. However, a partially instrumented system would be acceptable for tests in which the beam is passing through a small region of the detector at any particular time. In the minimal configuration the beam passes through a single counter in each of the planes, or 6 channels. This is not optimal because the cables need reconnection each time the beam or setup is moved, and there is no information from adjacent strips for each trigger. A reasonable compromise is to instrument a block of 8 adjacent strips at a time, or 48 channels. The signal cables could be accommodated in the 50-channel patch panel in MT6-B3, for example. For this we would need 48 channels of ADCs and 48 channels of discriminators, as well as supportive coincidence logic and scalers. There are 4 functional areas that require electronics:

1. We need to form a coincidence between the beam signal (B) and each of the 4 beam steering target counters (T_i). This requires fanning out the beam signal, coincidence units, and scalers to count the coincidences.
2. The targeted beam signal (B. T_i) for the selected target counter is then fanned out and put in coincidence with each of the 8 strip signals that are instrumented per module (S_{jk}), where i=1,8 strips and j=1,6 where j is PMT the number. (Recall that the double-sided readout units have 2 PMTs, one for each side.) This requires a total of 48 coincidence channels for the 4 modules, and 48 scaler channels. We also anticipate the need for amplifiers to boost the signals from the PMTs, and discriminators are needed for each of the signals.
3. The third logic area is the ADC function. Each of the 48 signals is connected to an ADC channel with a delay to arrive at the correct time with respect to the trigger gate.
4. In addition we need miscellaneous units such as gate generators to gate the scalers.

A list of units is in Appendix III.

2.2 BEAM

2.2.1 BEAM TYPES
We can operate with a variety of beam types. Our main requirements are rate and spot size. We need a spot size that is well contained within one strip. The 45° crossed

strips have a diamond-shaped overlap area that is about 6 cm by 6 cm in size, so a beam spot of about 1 cm x 1 cm would be very good. Our first choice for best rate and spot size is the 120 GeV positive beam, although we could run with lower energy beams. We also intend to test with muons after the efficiency mapping tests are completed. This would be after the March shutdown.

2.2.2 BEAM INTENSITY

We prefer running at 120 GeV positive beam, with ˜ 150 K particles per pulse. This gives us the smallest spot size as well. We could also operate at lower beam energies, but the data collection times would be increased. A detailed estimate of running time is given in section 2.2.4. As an example, a beam rate of 50 K per pulse would increase the time for coincidence measurements from 4 minutes per point to 12 minutes per point, and would not increase the time for ADC data collection or non-data collection task time. It would increase the overall time per point by 8 minutes, from about 17 minutes to about 25 minutes.

2.2.3 BEAM SHARING

Because of limited manpower availability and other commitments we would be unable to run continuously. We prefer to alternate beam time with other users. The amount of material we have in the beam would be 4 cm of scintillator for the test counters, 1 cm more for the beam defining counters, and 2 mm of aluminum for the packaging on the test counters. If this amount of material is not compatible with other users, the counters could be moved eastward out of the beam in either the MT6-B1 or the MT6-B4 location.

2.2.4 RUNNING TIME

Assuming a conservative figure for the particle rate at 120 GeV, 150 K per spill, two spills would give 300,000 beam particles, for 0.2% statistics for coincidence measurements. A typical scenario would be to do a horizontal scan across the counters; then move the counters to a new vertical position, and do the next horizontal scan, etc. Assuming a spill every 2 minutes the following more detailed scenario is envisaged:

1. Two pulses to collect coincidence data (4 minutes)
2. Unplugging the signal cables from the discriminators and connecting them to the ADCs in the control area, or vice versa (2 minutes)
3. Time to accumulate ADC data: LeCroy 2249 ADCs have a digitization time of 60 μsec, which limits the acquisition rate to 17000 per pulse. Two pulses are sufficient for a spectrum. (4 minutes). We are looking into the use of LeCroy 4300, 16 channel ADCs, which have a shorter digitization time.
4. Steer beam to hit next strip (5 minutes)
5. After every 4^{th} strip is hit, move the structure to next position, 4 strips over. At this time we would move the signal cables at the detector that connect to the panel in the MT6 area. (We do not intend to run cables and provide instrumentation for all channels at one time. We estimate that each move will take 10 minutes, so the time per strip is 2.5 minutes. (2.5 minutes). Each

move requires a 10 minute access to the test beam area, approximately once per hour.

The total time per point in a horizontal scan is 17.5 minutes, rounded to 20 minutes. For each scan there are 64 points, for a total of 21 hours per scan.

At the completion of each horizontal scan the apparatus must be moved vertically for the next horizontal scan. This should require an access of about 30 minutes. We anticipate about 8 vertical re-positions, or 4 hours. At present we are trying to simplify the structure to hold the detector by limiting the height of the structure. We are planning to have the highest position with the beam at the center vertically, and lower the detector to pass the beam through its upper half. Then we will remove the detector and rotate it 180º about a horizontal axis, and remount it do the other of the scans on the other half in the same manner. See section 2.3 below. We anticipate doing the rotation once or twice, about 2 hours per rotation.

In total the data taking time for 8 full horizontal scans is 168 hours plus 8 hours for vertical re-positioning, and 2 hours for turning the detector around to expose the inaccessible end portions, or 180 hours. This would take about 4 weeks of running time at about 45 hours per week to complete the tests. Time permitting we would turn the detector around to expose the portion that is unable to move westward into the beam because of the limited space between the beam line and the west shielding wall. This would only be done when the beam is off for periods of 4 hours or more.

2.3 SETUP

The apparatus consists of 4 scintillation counters, each 1.25 m x 2.5 m, and a movable stand that holds the set of 4 counters. The 4 counters are mounted in a row along the beam, aligned relative to each other so that their active areas line up, approximately 10 cm apart. For a fixed beam position, the motion of the set would be in increments of about 6 cm to center the beam on individual strips, which are 4.1 cm wide at 45º. If we have control of the beam steering we would be able to hit 3-4 counters at any position. We also need 4 small scintillation counters in fixed positions across the beam to define the 4 beam positions. The set of 4 counters will be mounted as a unit, and the unit will move horizontally on a cart along rails transverse to the beam. For the pre-shutdown period the counter unit will be mounted on a simple cart, and instead of moving the counter unit vertically upward to position the beam on the lower half of the counters we plan to move the unit downward to expose its upper half to the beam, then rotate the counter around so the lower half is above the beam line. Then we lower the unit by increments to do the remaining horizontal scans. We require the use of an A-frame to install the unit in the cart and to lift out the unit to turn the unit over. We are considering building rotation capability on the cart to allow rotation.

2.4 SCHEDULE

We propose to begin installing the equipment and setting up the electronics in late January, begin data-taking in mid-February, and to take data for about 4 weeks before the March shutdown. The second phase of running is after the March shutdown. If access to the test area is not available to install the equipment prior to the shutdown we would set up the equipment during the March shutdown and run the tests after the shutdown.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

([] denotes replacement cost of existing hardware.)

3.1 Indiana U.: Support stand for counters (to be provided).	$10 K
3.2 U. of Notre Dame: 4 prototype scintillation counter modules.	[$20 K]
3.3 Wayne State U.: Electronics for LED calibration monitors; Wiring of MAPMT bases (?).	$2 K
3.4 U. of Cal. at Davis: Software for DAQ, hardware for DAQ	[$5 K]

Total: $37 K

IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 Fermilab Accelerator Divisions:

4.1.1 Use of MTest beam.

4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.

4.1.3 A scaler or beam counter signal should be made available in the counting house.

4.1.4 Reasonable access to our equipment in the test beam.

4.1.5 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR).

4.1.6 Position and focus of the beam on the experimental devices under test will be under control of MCR. Control of secondary devices that provide these functions may be delegated to the experimenters as long as it does not violate the Shielding Assessment or provide potential for significant equipment damage.

4.1.7 The integrated effect of running this and other SY120 beams will not reduce the antiproton stacking rate by more than 5% globally, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

4.2 Fermilab Particle Physics Division

4.2.1 The test-beam efforts in this MOU will make use of the Meson Test Beam Facility. Requirements for the beam and user facilities are given in Section 2. The Fermilab Particle Physics Division will be responsible for coordinating overall activities in the MTest beam-line, including use of the user beam-line controls, readout of the beam-line detectors, and MTest gateway computer. [0.5 person weeks]

4.2.2 LINUX box computing support as needed (J. Ormes).[0.5 person weeks]

4.2.3 Artwork and printed circuit boards for MAPMT base connectors (6 needed). [2 person weeks]. Miscellaneous cables may be needed.

4.3 Fermilab Computing Division

4.3.1 Ethernet and printers should be available in the counting house.

4.3.2 Connection to beams control console and remote logging (ACNET) should be made available in the counting house.

4.3.3 Assistance with setup of CAMAC system. [0.5 person weeks]

4.3.4 See Appendix II for summary of PREP equipment pool needs.

4.4 Fermilab ES&H Section

4.4.1 Assistance with safety reviews.

4.4.2 Loan of radioactive source (preferably 1 mCi Cs^{137}) for the duration of the test beam.

V. Summary of Costs

Source of Funds [$K]	**Equipment**	**Operating**	**Personnel** (person-weeks)
Particle Physics Division	$5.0 K	$0 K	1.0
Beams Division	0	0	0
Computing Division	0	0	0.5
Totals Fermilab	$5.0 K	0	1.5
Totals Non-Fermilab	[$37 K]		

VI. SPECIAL CONSIDERATIONS

6.1 The responsibilities of the ILC Muon Test Group Spokesperson and procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters" (PFX). The Physicist in charge agrees to those responsibilities and to follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating a Partial Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The ILC Muon Test Group Spokesperson will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.

6.3 The ILC Muon Test Beam Spokesperson will ensure that at least one person is present at the Meson Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiment's hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.5 All items in the Fermilab Policy on Computing will be followed by experimenters.

6.6 The ILC Muon Test Group Spokesperson will undertake to ensure that no PREP and computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

6.7 Each institution will be responsible for maintaining and repairing both the electronics and the computing hardware supplied by them for the experiment. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.8 If the experiment brings to Fermilab on-line data acquisition or data communications equipment to be integrated with Fermilab owned equipment, early consultation with the Computing Division is advised.

6.9 At the completion of the experiment:

6.9.1 The ILC Muon Test Group Spokesperson is responsible for the return of all PREP equipment, Computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the RPC Detector Research Group Spokesperson will be required to furnish, in writing, an explanation for any non-return.

6.9.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters.

6.9.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied, including computer printout and magnetic tapes.

6.9.4 An experimenter will report on the test beam effort at a Fermilab All Experimenters Meeting.

SIGNATURES:

______________________________ / / 2005
Robert Abrams, Indiana University

______________________________ / / 2005
Jim Strait, Particle Physics Division

______________________________ / / 2005
Roger Dixon, Accelerator Division

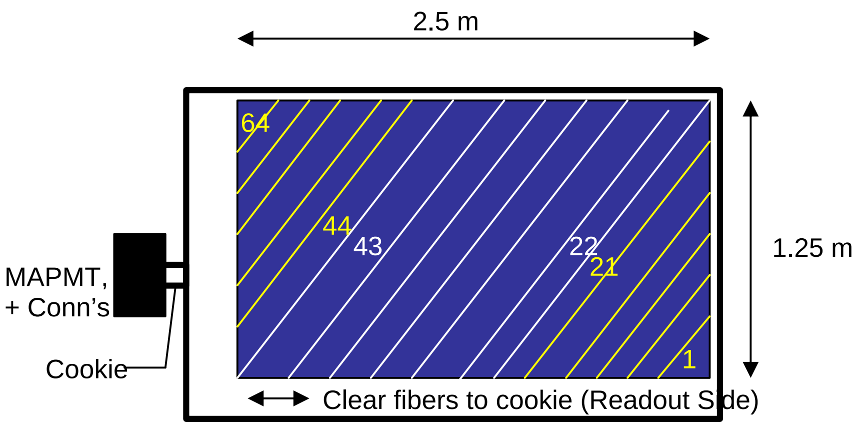
______________________________ / / 2005
Robert Tschirhart, Computing Division

______________________________ / / 2005
William Griffing, ES&H Section

______________________________ / /2005
Hugh Montgomery, Associate Director, Fermilab

______________________________ / /2005
Steven Holmes, Associate Director, Fermilab

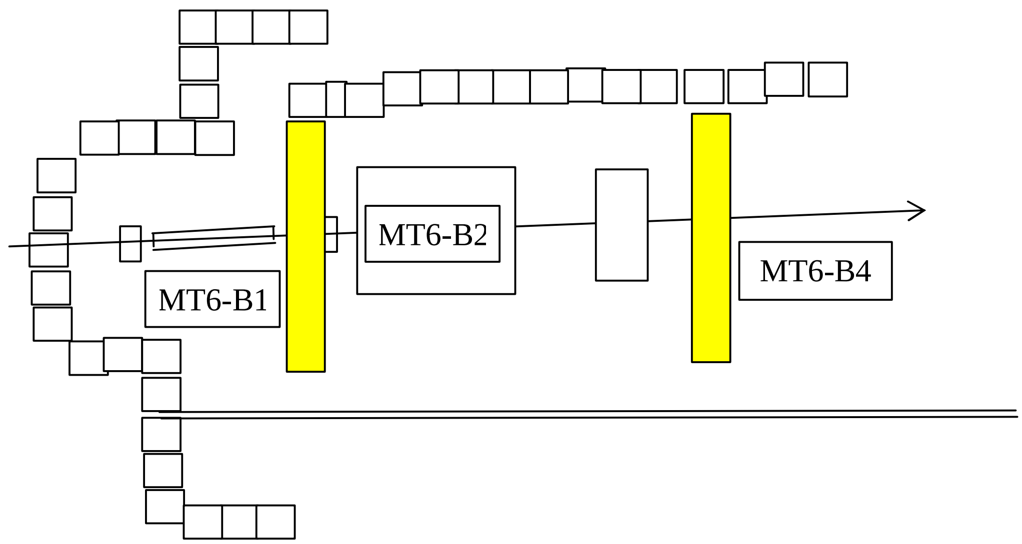
Appendix I: ILC Muon Detector Module Layout with Single-ended Readout
The outer dimensions are 2.8 m x 1.35 m. The double-sided readout modules are 2.8 m x 1.4 m, with 2 MAPMTs at the same end.



Schematic of Test Module with Single Sided Reado

APPENDIX II: MTEST LAYOUT WITH TWO POTENTIAL APPARATUS LOCATIONS

The apparatus could be tested in the MT-B1 area, which would necessitate moving the PWC just upstream of MT6-B2 or in the MT6-B4 area, downstream of the movable table, as indicated in yellow. In either location the detector is limited in travel by the West shielding wall, but the coverage is slightly better in the MT6-B1 area.



APPENDIX III: ILC MUON TESTS – EQUIPMENT NEEDS

Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup. Numbers in brackets [] are the numbers of units that we currently are using in Lab 6, and could move to MTEST.

Quantity	Description
6	Nim crates, with cooling fans [3]
1	Camac crate, powered [1]
4	Camac Lecroy 2249 ADC for 48 phototube signals (or 3 Lecroy 4300 FERA) [22249s with several dead channels]
3	16-channel LeCroy 4616 or equivalent 16-channel NIM-ECL translator/adapter [1]
12	NIM Octal discriminators Lecroy 623B [1]
15	NIM logic fan out Lecroy 428/429 [2]
6	Visual scaler channels with presets [4]
2	NIM gate generators Philips 794 or similar [2]
4	NIM 12-signal amplifiers Lecroy 612 or similar [1]
12	NIM quad-coin. 2-fold logic Lecroy 621/622 or similar [4]
2	NIM quad discriminators, LeCroy 821 or equivalent [5]
24	NIM dual delay modules to delay the 48 MAPMT signals to the ADCs [0]
2	HV supplies for Scintillation counters utilizing PMTs and dividers, 1 to support 4 finger beam defining counters(up to 2500V) and 1 to support 6 MAPMTs (max voltage 1000 V) [2]
1	analogue or 1 digital oscilloscope [1 each]
10	SHV cables from detector to patch panel in MTEST [6]
10	SHV cables from MTEST patch panel to counting house
52	RG58 / BNC cables from scintillation counters to MTEST patch panel [have 64 32ns cables]
52	RG158 cables from MTEST patch panel to counting house
100	Lemo cables, various lengths [have ~50]

APPENDIX V - Hazard Identification Checklist

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
	Beam line magnets		Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	**X**	high voltage		
	Bubble chamber		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
	inside diameter	Type:			
	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
	inside diameter	**X**	temporary use		Beryllium (Be)
	operating pressure	Type:	**CS137**		Lithium (Li)
	window material	Strength:	**3 mCi**		Mercury (Hg)
	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		Scintillation Oil		Uranium (U)
X	Temporary installation		PCBs		Other
	Calibration		Methane	**Mechanical Structures**	
X	Alignment		TMAE	**X**	Lifting devices
type:			TEA	**X**	Motion controllers - manual
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other: Activated Water?		Others